

At page 10, last two lines of the last paragraph replace "as silicon" with - - as a silicon-containing compound - -.

In the Claims:

Cancel claim 50.

Please amend claims 1, 3, 6, 7, 19-33, 41, 43, 44, 47, and 49 as follows:

- Sub B² G1
1. (amended) A method for removing from a microelectronic device structure a noble metal residue including at least one metal selected from the group consisting of platinum, palladium, iridium and rhodium, the method comprising contacting the microelectronic device structure with a gas-phase reactive halide composition comprising a halide component selected from the group consisting of SF₆, SiF₄, Si₂F₆, SiF₂ radical, SiF₃ radical, and XeF₂, in an amount effective to remove the residue.

- G2
3. (amended) The method according to claim 1, wherein the reactive halide composition [is selected from the group consisting of] comprises SF₆, SiF₄, and Si₂F₆.

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(amended) The method according to claim 1, wherein the microelectronic device structure is disposed in a chamber, said method further comprising: evacuating the chamber, filling the chamber with a cleaning gas comprising the reactive halide composition, and retaining the reactive halide composition in the chamber to react with the residue [,] for a time sufficient to effect removal of the noble metal residue from the microelectronic device structure.

- G3
- Sub B³
7. A method according to claim 6, wherein the pressure of the cleaning gas is from about 50 mTorr to about 2 Torr, and the [reaction time for] each fill of the cleaning gas is maintained in the chamber for a period of time which is from about 10 seconds to about 10 min.

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(amended) [The method according to claim 1, wherein the noble metal residue comprises] A method for removing from a microelectronic device structure a noble metal residue comprising iridium, the method comprising contacting the microelectronic device structure with a gas-phase reactive halide composition [and a cleaning gas] comprising [the reactive halide composition] XeF₂ to remove the residue.

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1420. (amended) The method according to claim 19, further comprising, contacting the microelectronic device structure with [a cleaning enhancement] an agent to assist in volatilizing and removing the noble metal residue on the microelectronic device structure.

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1521. (amended) The method according to claim 20, wherein the [cleaning enhancement] agent is selected from the group consisting of [Lewis-base adducts] Lewis bases and electron back-bonding species.

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11622. (amended) The method according to claim 20, wherein the [cleaning enhancement] agent is selected from the group consisting of carbon monoxide, trifluorophosphine, and trialkylphosphines.

23. (amended) The method according to claim 22 wherein the [cleaning enhancement] agent comprises an iridium halide species selected from the group consisting of Ir(X)₁, Ir(X)₃, Ir(X)₄ and Ir(X)₆, wherein X represents the halide of the reactive halide composition.

24. (amended) The method according to claim 19, wherein:

(a) the cleaning gas further [comprising] comprises a gas phase reactive halide species selected from the group consisting of SF₆, SiF₄, Si₂F₆, [and] SiF₂ radical and SiF₃ radical; [radicals] and

(b) the microelectronic device structure, is further contacted with [a cleaning enhancement] an agent to assist in volatilizing and removing the noble metal residue on the microelectronic device structure.

25. (amended) The method according to claim 24, wherein the [cleaning enhancement] agent is selected from the group consisting of [Lewis-base adducts] Lewis bases and electron back-bonding species.

26. (amended) The method according to claim 24, wherein the [cleaning enhancement] agent is selected from the group consisting of carbon monoxide, trifluorophosphine, and trialkylphosphines.

27. (amended) The method according to claim 24 wherein the [cleaning enhancement] agent comprises an iridium halide species from the group consisting of $\text{Ir}(\text{X})_1$, $\text{Ir}(\text{X})_3$, $\text{Ir}(\text{X})_4$ and $\text{Ir}(\text{X})_6$, wherein X represents the halide of the reactive halide composition.

- 117/28. (amended) The method according to claim 1, wherein the contacting of the microelectronic device structure with the gas phase reactive halide composition is carried out with [a cleaning enhancement] an agent to assist in volatilizing and removing the noble metal residue on the microelectronic device structure and the contacting comprises an enhancement step selected from the group consisting of:

- (a) providing an inert gas in the [cleaning enhancement] agent;
- (b) carrying out the contacting in an ion-beam-assisted manner;
- (c) carrying out the contacting in a plasma-assisted manner;
- (d) carrying out the contacting in a photo-assisted manner; and
- (e) carrying out the contacting in a laser assisted manner.

- 118/29. (amended) The method according to claim 1, wherein the noble metal residue comprises iridium, and carbon monoxide is present in the gaseous mixture during the contacting.

- 119/30. (amended) The method according to claim 1, wherein a hexafluoride compound of the noble metal is present in the gaseous mixture during the contacting.

- 20/31. (amended) The method according to claim 1, wherein a silicon fluoride compound is present in the gaseous mixture during the contacting.

- 21/32. (amended) The method according to claim 1, wherein the noble metal residue comprises iridium, and IrF_6 is present in the gaseous mixture during the contacting.

- 22/33. (amended) The method according to claim 1, wherein a Lewis base ligand is present in the gaseous mixture during said contacting, to enhance the removal of the noble metal residue.

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(amended) A method for removing from a microelectronic device structure a noble metal residue comprising [including at least one metal selected from the group consisting of platinum, palladium,] iridium, [and rhodium,] the method comprising contacting the microelectronic device structure with a cleaning gas comprising gas-phase XeF_2 to at least partially remove the noble metal residue.

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(amended) The method according to claim ~~41~~³⁰ wherein elemental silicon is exposed within the reaction chamber during [present with the gas-phase XeF_2 in] said contacting.

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(amended) The method according to claim ~~41~~³⁰, wherein the microelectronic device structure is disposed in a chamber, said method further comprising evacuating the chamber, filling the chamber with the cleaning gas [XeF_2], and retaining the cleaning gas in the chamber to react with the residue, to effect the removal of the noble metal residue from the microelectronic device structure.

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47. The method according to claim 41, wherein the microelectronic device structure is disposed in a chamber, and the [cleaning gas comprising a] gas phase XeF_2 [reactive halide composition selected from the group consisting of SF_6 , SiF_4 and Si_2F_6] is continually flowed through the chamber, in combination with an energetic dissociation source.

49. (amended) The method according to claim 46, wherein the cleaning gas [phase reactive halide composition is] further comprises one or more radicals selected from the group [of radicals] consisting of SiF_2 and SiF_3 .

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Please add the following new claims 51-56:

51. The method according to claim 1, wherein the reactive halide composition comprises SiF_4 .

52. The method according to claim 1, wherein the reactive halide composition comprises Si_2F_6 .

53. The method according to claim 1, wherein the microelectronic device structure is disposed in a chamber, said method further comprising:

(a) evacuating the chamber;

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- 7
- (b) filling the chamber with a cleaning gas comprising the reactive halide composition; and
 - (c) retaining the reactive halide composition in the chamber to react with the residue; and
 - (d) sequentially repeating said steps of filling and evacuating to effect removal of the noble metal residue from the microelectronic device structure.

54. A method for removing from a microelectronic device structure a noble metal residue comprising at least one metal selected from the group consisting of platinum, palladium, iridium and rhodium, the method comprising contacting the microelectronic device structure with a gas-phase reactive halide composition comprising a halide component selected from the group consisting of SF₆, SiF₄, Si₂F₆, SiF₂ radical, SiF₃ radical, and XeF₂, in an amount and for a time sufficient to remove the residue.

- 40/55. A method for etching a noble metal composition comprising iridium comprising contacting the noble metal with an etchant comprising XeF₂.

- 41/56. A method for etching iridium comprising contacting the iridium with an etchant comprising XeF₂.

REMARKS

The applicants acknowledge the Examiner's renumbering of original claims 49-51 as 48-50. Claim 50 has been cancelled. Claims 1-49 and 51-56 are pending in the application.

1. Objections to the Specification

The amendments presented herein and the following comments overcome all objections to the specification¹.

With regard to the Examiner's objection to the phrase "another compound, such as silicon" at page 10 of the specification, the applicants have amended the phrase in question to recite "another compound, such

as a silicon-containing compound.” This change reflects the meaning that would be naturally attributed to the original phrase by one of ordinary skill in the art.

The Examiner has proposed a purported equivalent to the formula on page 11, suggesting that “(CO)_yIr(X)₁₋₆” should be replaced with “--(CO)_yIr(X)_{6-y}--”. However, the formula “(CO)_yIr(X)₁₋₆” is readily understandable to one of skill in the art. An ordinarily skilled chemist can readily balance the number of (CO) and (X) groups based on the valence of Ir.

With regard to the Examiner’s objection to the bridging sentence of pages 13-14, the sentence in question would not be confusing to one of ordinary skill in the art. Moreover, the Examiner has not identified any particular aspect of the sentence which the Examiner considers to be confusing. The sentence refers by the introductory phrase “as mentioned” to the section of the application in which prior art wet methods are discussed. At page 3, second paragraph, the specification explains that in the use of wet rinsing techniques, “a significant fraction of the residue may be transported in suspension in the rinse media, allowing a small fraction of the residue solids to redeposit on the wafer and thereby reducing device yield”(emphasis added). The phrase “decreased throughput” would be readily understood by one of skill in the art to indicate that the wet rinsing techniques slow down the manufacturing process, resulting in decreased productivity. The sentence is therefore clear and readily understandable to one of skill in the art.

2. Objections to the Claims²

Claims 21 and 25 are amended to recite “Lewis bases” rather than “Lewis-base adducts.”

Claims 23 and 27 have been amended to replace “cleaning enhancement agents” with “agents.” The term “cleaning enhancement agents” is clear and readily understandable to one of skill in the art. However the change to “agents” is readily made without diminishing the clarity or scope of the affected claims, since the base claim 20 describes the agent as “assist[ing] in volatilizing and removing the noble metal residue on the microelectronic device structure.” The Examiner cited claims 30 and 32 in connection with this rejection; however, claims 30 and 32 do not contain the term “cleaning enhancement agent.”

¹ See the October 8, 1999 Office Action, paragraph 3.

² *Id.*, paragraph 5.

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Claims 29-33 and 43 have been amended to recite that the species is "present in the gaseous mixture during the contacting."

Claim 44 has been amended to recite "retaining the cleaning gas in the chamber . . ."

Claim 50 has been cancelled.

The foregoing amendments and arguments overcome all objections to claims 21, 23, 25, 27, 29-33, 43 and 44. The applicants request the Examiner to reconsider and withdraw all such objections.

3. The claims satisfy the definiteness requirement of 35 U.S.C. § 112, second paragraph.

With regard to claim 7, the antecedent basis rejection of paragraph 8 of the Office Action has been overcome by amending the claim to recite that "each fill of the cleaning gas is maintained in the chamber for a period of time which is from about 10 seconds to about 10 min."

Claim 23 has been amended to recite "the agent" rather than "the cleaning enhancement agent." This amendment overcomes the antecedent basis rejection in paragraph 9 of the Office Action.

Claim 24 has been amended to recite "the group consisting of SF₆, SiF₄, Si₂F₆, SiF₂ radical and SiF₃ radical." This amendment overcomes the indefiniteness rejection of paragraph 10 of the Office Action.

Claim 43 has been amended to recite that "elemental silicon is exposed within the reaction chamber during said contacting." This amendment overcomes the indefiniteness rejection of paragraph 11 of the Office Action.

Claim 47 has been amended to recite that "the gas phase XeF₂ is continually flowed through the chamber." This amendment overcomes the antecedent basis rejection set forth in paragraph 12 of the Office Action.

Claim 41 has been amended to recite "a cleaning gas comprising gas phase XeF₂." Claim 49 has been amended to refer to "the cleaning gas." These amendments overcome the antecedent basis rejection of claim 49 as set forth in paragraph 13 of the Office Action.

4. The claimed invention is novel and nonobvious in view of Ashby et al. and in view of Smith et al.

The Examiner indicated in the October 8, 1999 Office Action that "[t]he use of XeF₂ as a component of an etchant to etch Iridium is a novel feature."³ The applicants have therefore amended claim 41 to recite:

41. A method for removing from a microelectronic device structure a noble metal residue comprising iridium, the method comprising contacting the microelectronic device structure with a cleaning gas comprising gas-phase XeF₂ to at least partially remove the noble metal residue.

Claim 41, and claims 42-49, which depend from claim 41, are therefore novel and nonobvious on the basis stated by the Examiner. The novelty of claim 41 and claims depending therefrom having been established, the following remarks in Sections 4.1 and 4.2 relate primarily to the novelty and nonobviousness of claims 1-39.

4.1 The claimed invention is novel and nonobvious in view of Ashby et al.

The Examiner has rejected of claims 1 and 15-18 is based on the proposition that Ashby et al. "teaches a method that uses a gas phase reactive halide composition for removing contaminants of Pt, Pd, Ir and Rh from a wafer's surface." Claim 1 is amended to require the halide composition to comprise a halide component selected from the group consisting of: SF₆, SiF₄, Si₂F₆, SiF₂ radical, SiF₃ radical, and XeF₂ *in an amount effective to remove the residue*. Ashby et al. does not teach or suggest the use of these specific compounds in an amount effective to remove the residue.

With regard to claim 3, the Examiner contends that "[a]s a reactive halide Ashby et al. teaches the use of SF₆."⁴ However, Ashby et al. teaches the use of SF₆ only as an "intermediary reactant species" for use with a class of cleaning agents termed " π -acceptor ligands":

According to the present invention, the exposed portion [of a transition metal thin film, defined by openings in a masking layer over the thin film,] may be removed by providing at least one nitrogen- or phosphorous-containing π -acceptor ligand in proximity to the transition metal thin film and dry etching the transition metal thin film and forming a volatile complex comprising the nitrogen- or phosphorous-containing π -acceptor ligand and the transition metal. In some preferred embodiments of the present invention, *an intermediary reactant species (such as a halide ligand and/or a carbonyl ligand) may be provided in addition to the nitrogen- or phosphorous-containing π -acceptor ligand, with the intermediary species forming an intermediary reaction product or complex*

³ *Id.*, paragraph 20.

⁴ *Id.*, page 6, first and second paragraphs.

*with the transition metal prior to a further chemical reaction with the nitrogen- or phosphorous-containing π -acceptor ligand for forming a final reaction product comprising a volatile transition metal/ π -acceptor ligand complex.*⁵

Ashby et al. provides SF₆ as an example of an intermediary reactant species. According to Ashby et al., the “intermediary reactant species . . . may be provided *in addition to* the nitrogen- or phosphorous-containing π -acceptor ligand”⁶ for etching the transition metal. The intermediary reactant species (such as SF₆) is capable only of “*forming an intermediary reaction product*”⁷ which can then be volatilized *only in the presence of the π -acceptor ligand*.⁸ Ashby et al. emphasizes this point by using the term “intermediary reactant product.” It is only after the formation of a “*final* reaction product” using the π -acceptor ligand that etching occurs.

Moreover, the intermediary reactant species of Ashby et al. are not present “in an amount effective to clean the residue,” as is required of the halide species enumerated in claim 1.⁹

With regard to claims 4, 13, 14, and 30-32, even assuming for the sake of argument, that SiF_x species, including radicals, are inherently present in the method of Ashby et al.,¹⁰ such species are clearly not present “*in an amount effective to remove the residue*” (emphasis added). Furthermore, as previously discussed, Ashby et al. teaches the use of SF₆ only as an intermediary species. Ashby et al. does not contemplate, much less teach, the use of SF₆ as a cleaning agent present “in an amount effective to remove the residue.”

With regard to claim 5, while Ashby et al. teaches operating at a temperature of up to about 200° C, this operational limitation is in the context of using π -acceptor ligands as cleaning agents and not in the context of using the claimed halide components as cleaning agents. In fact, the context of the specific text cited by the Examiner is as follows:

For a particular transition metal (or transition metal alloy) to be etched, a predetermined nitrogen- or phosphorous-containing π -acceptor ligand is preferably selected to provide a final reaction product complex (i.e. a volatile complex) having sufficient

⁵ Ashby et al., U.S. Patent 5,814,238, column 4, lines 43-58.

⁶ *Id.* at column 4, lines 50-53; as examples of halide ligands, Ashby et al. lists: “Cl₂, BCl₃, NOCl, NOBr, BrF₃, HF, F₂, BF₃, CF₄, COF₂, NOF and SF₆.”

⁷ *Id.* at column 4, lines 53-54.

⁸ *Id.* at column 4, lines 55-58.

⁹ It is noted that the claims as amended do not exclude method steps which may employ “ π -acceptor ligand.” The novelty of claim 1, and the claims which depend therefrom, is based, *inter alia*, on the required presence of the specified halide components “in an amount sufficient to clean the residue.”

¹⁰ The applicants do not concede that SiF_x species are inherently present in the method of Ashby.

volatility for withdrawal from the reaction chamber by a vacuum pump connected thereto. According to some embodiments of the present invention, it may be preferable or necessary to heat the stage or carriage containing one or more predetermined substrates to be etched with a heater for sublimating the final reaction product complex for removal thereof. In these embodiments of the present invention, the stage or carriage is preferably heated and maintained at a temperature of up to about 200° C. or higher, with the exact temperature being determined by thermal characteristics or limitations of any masking layer (e.g a photoresist or the like) provided on the substrates for defining the portion of the metal thin-film to be etched for forming the interconnects.

The context of the 200° C process limitation is therefore as follows:

- a nitrogen- or phosphorous-containing π -acceptor ligand is being used to provide the final volatile reaction product;
- no intermediary reactant species (such as SF₆) is being used; and
- the process being performed is etching, not cleaning.

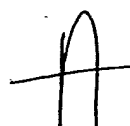
Ashby et al. emphasizes that the “nitrogen- or phosphorous-containing π -acceptor ligand is preferably *selected to provide a final reaction product complex (i.e. a volatile complex) having sufficient volatility* for withdrawal from the reaction chamber by a vacuum pump.”¹¹ In other words, the volatilization and therefore the cleaning is performed by the π -acceptor ligand. In this embodiment of the Ashby et al. method, *no intermediate reactant species is being used*. The specified temperature limitation is therefore irrelevant to the novelty of claim 5, since the temperature limitation of claim 5 is in the context of a different cleaning agent.

With regard to claim 6, as discussed above, Ashby et al. does not teach the use of the specific halide components of the composition required by the applicants claimed method in an amount effective to remove the noble metal residue. Therefore, Ashby et al. does not anticipate claim 6.

The Examiner argues that, with regard to claims 8 and 9, Ashby et al. teaches a flow rate of 11 sccm and pressure of 125 mTorr. However, again, since this teaching is not in reference to the specific halide composition required by the claimed method, these specific process limitations disclosed by Ashby et al. are not relevant to the novelty of claims 8 and 9.

With regard to claims 28, 29 and 33, the Examiner contends that Ashby et al. teaches the use of a cleaning enhancement agent/Lewis base and an inert gas and a plasma. However, in Ashby, these elements are

¹¹ Ashby et al. at column 7, lines 7-11 (emphasis added).



taught in the context of a different cleaning agent. Ashby et al. therefore does not teach each and every limitation of claims 28, 29 and 33 and does not anticipate such claims.

The claimed invention is also nonobvious in view Ashby et al. In addition to the elements discussed above which are not taught or suggested by this reference, Ashby et al. teaches away from the claimed invention. "A reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the applicant."¹² Ashby et al. teaches that an intermediary reactant species (such as a SF_6) is *useful only when used in addition to* the nitrogen- or phosphorous-containing π -acceptor ligand.¹³ A person of ordinary skill would be discouraged by Ashby et al. from attempts to utilize the *intermediary reactant species* in an amount sufficient to clean noble metal residue.

4.2 The claimed invention is novel and nonobvious in view of Smith et al.

Claim 1 recites a method for removing a noble metal residue and require a "reactive halide composition comprising a halide component selected from the group consisting of : SF_6 , SiF_4 , Si_2F_6 , SiF_2 radical, SiF_3 radical, and XeF_2 , *in an amount effective to remove the residue.*" Smith et al. teaches method for etching and not a cleaning process as claimed by the applicant.

With regard to XeF_x and SF_6 , Smith et al. teaches etching "an anti-reflective coating/etch stop layer of *titanium-tungsten alloy*" using "a chemical species which does not contain carbon," such as XeF_x or SF_6 .¹⁴ Smith et al. does not teach or suggest the use of XeF_x or SF_6 in removing "a noble metal residue including at least one metal selected from the group consisting of *platinum, palladium, iridium and rhodium,*" as required by claim 1 and claim 15 (which depends from claim 1).

With regard to PtF_6 , claim 1 requires the presence of "a halide component selected from the group consisting of : SF_6 , SiF_4 , Si_2F_6 , SiF_2 radical, SiF_3 radical, and XeF_2 , in an amount effective to remove the residue." While this limitation does not exclude PtF_6 from the halide composition, it adds an element to the claim which is not taught or suggested by Smith et al. Accordingly, the teaching of Smith et al. concerning PtF_6 is not relevant to the patentability of claims 4, 12-14, 30-32.

¹² *In re Gurley*, 31 U.S.P.Q.2d 1130, 1131 (Fed. Cir. 1994).

¹³ Ashby et al. at column 4, lines 50-53.

¹⁴ Smith et al. U.S. Patent 5,911,887, column 5, lines 53-60.

With regard to SiF_x , and radicals, even assuming for the sake of argument that these components are in the compositions recited in the claimed methods, there is no teaching or suggestion that they are present *“in an amount effective to remove the residue,”* as is required by claim 1 and the claims which depend therefrom.

Claim 6 is amended to specify that the reactive halide composition is retained “in the chamber to react with the residue, *for a time sufficient to effect removal of the noble metal residue . . .*” Since Smith et al. does not teach or suggest the use of the claimed halide components in an amount, or for a time, sufficient to effect removal of the claimed noble metal residues, Smith et al. does not anticipate claim 6 or claim 44.

With regard to the use of a cleaning enhancement agent/Lewis base and an inert gas and a plasma, Smith et al. does not teach these elements in the context of the applicants claimed process for cleaning noble metal residues using the specific halide components recited in claim 1. Smith et al. therefore does not teach each and every limitation of claim 28 or claim 33, both of which depend from claim 1.

The parameters recited in claims 7, 9, 42 and 45 are not a matter of the mere optimization of a process taught in Smith. These claims are limited to a cleaning process, while Smith et al. teaches an etching process. In addition to the specific novel features discussed above, these claims are nonobvious on the basis of the cleaning process parameters recited therein.

Claims 7, 9-11, 42 and 45 are nonobvious over Smith et al., *inter alia*, on the basis of the novel limitations as discussed above, none of which are taught or suggested by Smith et al.

All rejections based on Smith et al. have been overcome, and the Examiner is respectfully requested to withdraw such rejections.

5. Allowable Subject Matter

As suggested by the Examiner, claim 19 has been amended to incorporate the limitations of claim 1. Claim 19 is therefore in condition for allowance. Claims 20-22 and 25-27 all depend from claim 19 (or from claims which depend from claim 19), and are therefore in condition for allowance.

Claim 41 has been amended as described in Section 4 above to recite the use of XeF_2 as a component of a composition for cleaning a noble metal residue comprising iridium.